Posterior Aortic Annular Enlargement for Mechanical Aortic Valve Replacement

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A small aortic root is a challenging problem in congenital heart surgery, commonly seen in children with tri-leaflet, and occasionally bileaflet, aortic valve stenosis. Mixed aortic stenosis and regurgitation may be present, especially in patients who have previously undergone surgical or interventional procedures to relieve aortic stenosis. When long standing aortic regurgitation is present, however, a larger aortic annulus is more likely.

Prosthetic valves smaller than 17 mm in diameter are rarely manufactured since the effective orifice area of these valves would leave a substantial gradient. Because of the mathematical relationship ($A = \pi r^2$), even a small decrease in the radius of the valve leads to a substantial decrease in the cross-sectional area. Furthermore, the use of small prosthetic valves may produce prosthesis-patient mismatch, resulting in complications such as persisting left ventricular dysfunction or hypertrophy, hemolysis, and thrombosis.[1,2] Choosing a marginally sized prothesis has particularly far reaching consequences in children, who may have the potential for substantial further growth.

Management of the small aortic annulus initially involved bypassing the obstructive outflow tract using a conduit from the apex of the left ventricle to the descending aorta. This approach was supplanted by the three currently accepted alternative solutions: (1) Use of stentless tissue prosthesis, (2) enlargement of the aortic annulus, and (3) implantation of an adequate sized prosthesis in a tilted supra-annular position. In children, tissue valves are a poor choice because of their limited lifespan. Placement of a prosthesis in the tilted supra-annular position is likely to result in use of only a single size larger prosthesis than might be expected utilizing standard annular positioning. This is often inadequate when growth considerations are taken into account. Formal annular enlargement is, therefore, often the procedure of choice in young patients. The relatively recent introduction of the use of the pulmonary autograft to reconstruct the left ventricular outflow tract in children has had a major impact on the decision making process in young patients with aortic stenosis and small aortic root, and the autograft implantation may be combined with any of the various techniques of root enlargement. There are times, however, when the autograft is either contraindicated, or not preferred for a variety of reasons. In these cases, aortic root enlargement is combined with placement of a mechanical prosthesis.

Historically, posterior annular enlargement was the first of these techniques reported by Nicks and colleagues[3] in 1970. They proposed patch enlargement of the aortic annulus by extending the incision through the mid-portion of the noncoronary sinus through the aortic annulus. Subsequently, an alternative procedure was described whereby posterior annular enlargement is achieved by extending an oblique incision toward the commissure of the left coronary and noncoronary cusps, mitral annulus, and anterior mitral leaflet (AML) at it's midpoint, followed by reconstruction of this defect using a diamond shaped patch.[4] Although, there has been some controversy regarding the credit for the conception of the technique (Rastan-Manouguian),[5,6] most have come to recognize the procedure as the "Maouguian." At about the same time, Konno and colleagues described anterior annular enlargement by longitudinal incision of the aortic root along the commissure of the right and left coronary cusp with an extension onto the septum and the outflow tract of the right ventricle.[7] If need be, the two procedures, Manouguian and Konno, can be combined to obtain even further enlargement of the annulus, although this would be a rare situation.[8]

With the Nicks procedure, the incision can not be easily directed to the center of the AML and, hence, can not be extended across the mitral annulus, lest it cause leaflet distortion and resultant mitral regurgitation. In contrast, by means of the Manouguian procedure, not only the mitral leaflet, but also the left atrial attachment at the base of the aorta can be divided. Therefore, while with the Nick's procedure one is generally limited to a one-size larger prosthesis, with the Manouguian incision one can insert a two-size larger prosthetic valve.

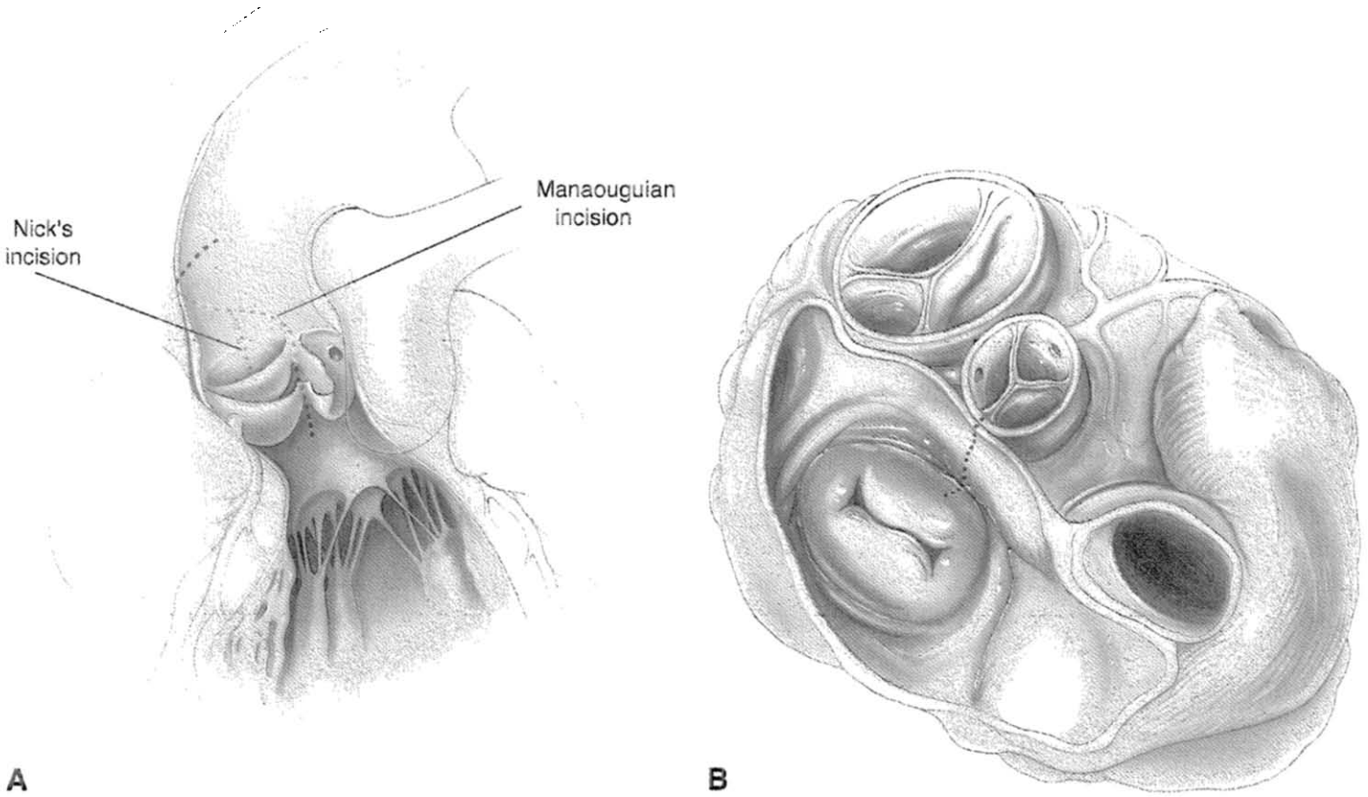
Often the small root presents in the context of multiple obstructive lesions involving the left side of the heart. Our preference for management of a small aortic root in a child with tunnel obstruction of the left ventricular outflow tract is the Konno procedure, since this would allow an opportunity to address not only the small root but also the accompanying subvalvar stenosis. Similarly, a Konno procedure is preferred when it

is expected that the prosthesis to be used is greater than two sizes larger than the native aortic root, even in the absence of tunnel subaortic stenosis. Aside from these circumstances, it is not uncommon for the small root to be present in an isolated context. A typical example, illustrated in this article, is an adolescent boy with congenital aortic stenosis who has undergone a few attempts at balloon valuvuloplasty as a neonate and infant, who continues with persistent gradient at the valvar level. Often, there is accompanying aortic insufficiency. Indeed, aortic insufficiency would be more pronounced in these children than those with subvalvar obstruction because of limitation of backward flow by the subvalvar element.

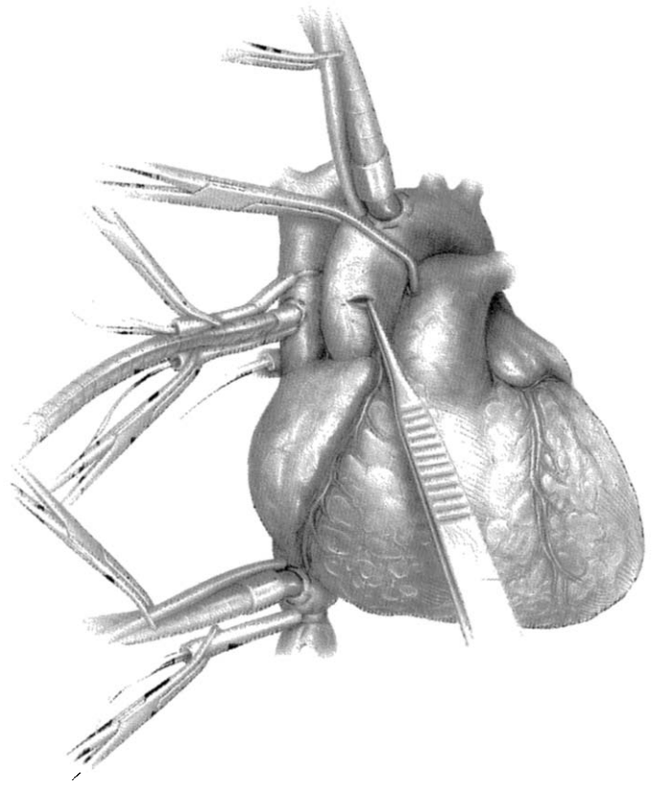
Other indications for the use of a posterior root enlarging procedures include the need for replacement of the mitral valve simultaneous with the aortic valve[9,10] and need for repeat or further root enlargement after a previous Konno procedure.[11] Furthermore, in an infant with combined mitral and aortic stenosis, enlargement of the mitral and aortic annuli could be accomplished simultaneously.

If simultaneous aortic and mitral replacement is performed, careful inspection of the left ventricular outflow tract is mandated. The ring of a large mitral prosthesis may protrude into this space, defeating the original goal of the operation.[12] Furthermore, the placement of a rigid mitral prosthesis can reduce the effective available space for the placement of the aortic prosthesis. Therefore, the aortic annulus should be resized after placement of the mitral valve prosthesis before commencement of aortic valve replacement. Alternatively, the aortic valve prosthesis may be seated before mitral valve replacement, although this could make the placement of the sutures through the anterior annulus of the mitral valve somewhat cumbersome. Sankar and coworkers have reported that in patients undergoing double valve replacement, enlargement of the aortic-mitral curtain by more than 30 mm leads to protrusion of the mitral prosthesis under the aortic prosthesis.[13]

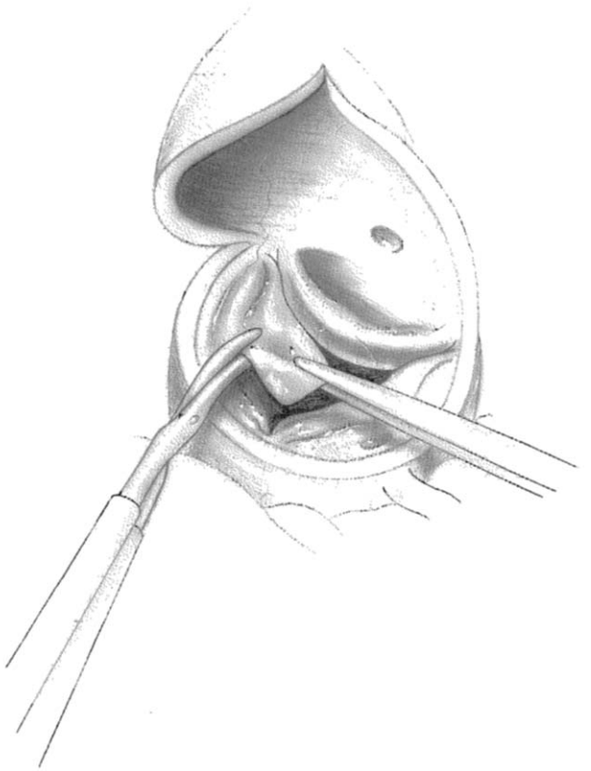
PROCEDURE



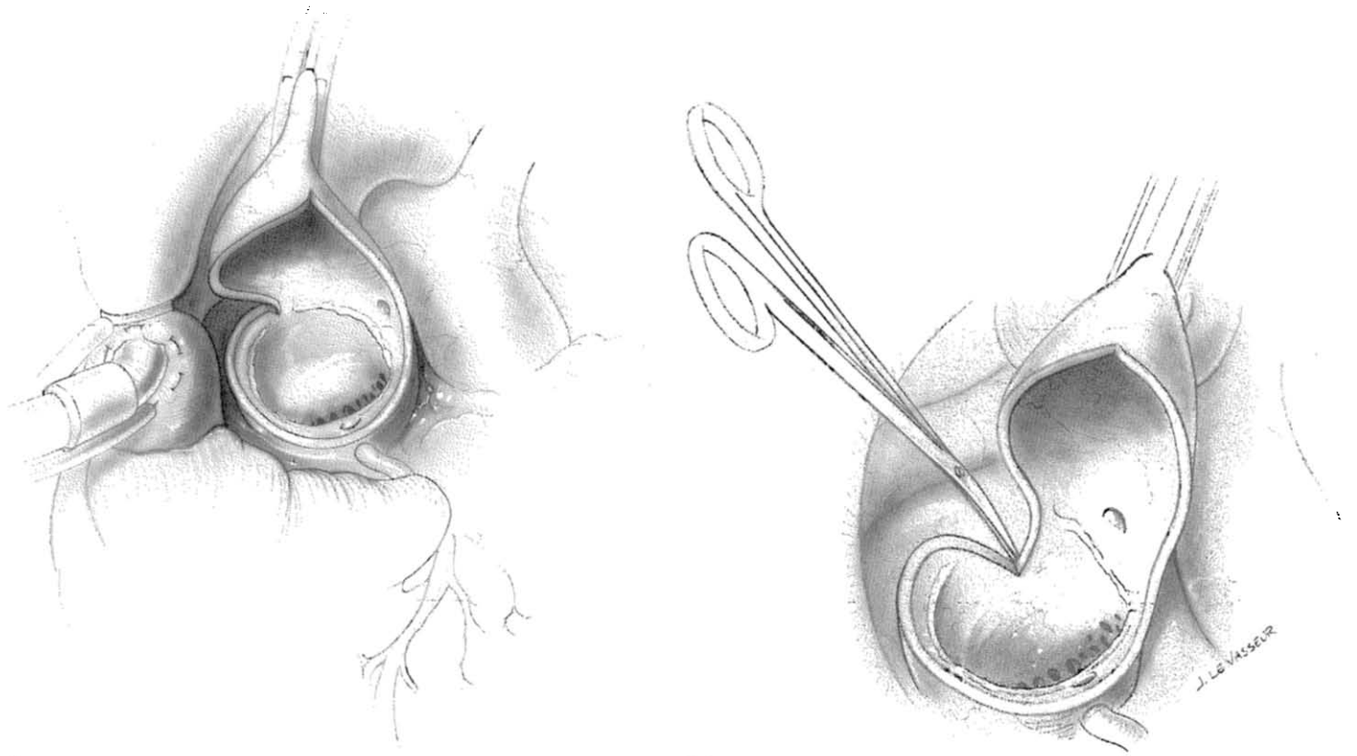
1 A schematic of the aortic annulus and the AML are shown, demonstrating the different lines of incision (Fig 1). In Nick's method, the aortic incision is carried downward through the noncoronary aortic sinus across the aortic ring as far as the origin of the mitral valve. In Manouguian's incision, the aortic incision is extended through the intervalvular trigone between the left coronary commissure (LCC) and the noncoronary commissure (NCC). In the latter, the incision is readily directed to the exact center of the AML. Note that because of the close vicinity of the origin of the NCC to the mitral ring, the aortic ring itself is usually widened only a few millimeters in Nicks' method. If need be, the inserted prosthetic valve may be placed in an oblique fashion by lifting one edge at the enlarged NCC area.



2 Incision and median sternotomy are performed in the standard fashion (Fig 2). In a redo procedure, if possible, all retrosternal adhesions are taken down under direct vision. Bicaval cannulation is performed along with the placement of an aortic cannula in the very distal aspect of ascending aorta, just proximal to the takeoff of the inominate artery. Hypothermic (28°C) cardiopulmonary bypass is established and a vent is placed in the right superior pulmonary vein at its junction with the left atrium. Caution is warranted during this procedure if there is significant aortic insufficiency, because the to and fro motion of blood in the left ventricle could lead to accidental sucking of air into the LV and its ejection. In this instance, the vent could be placed after placement of the aortic cross clamp.

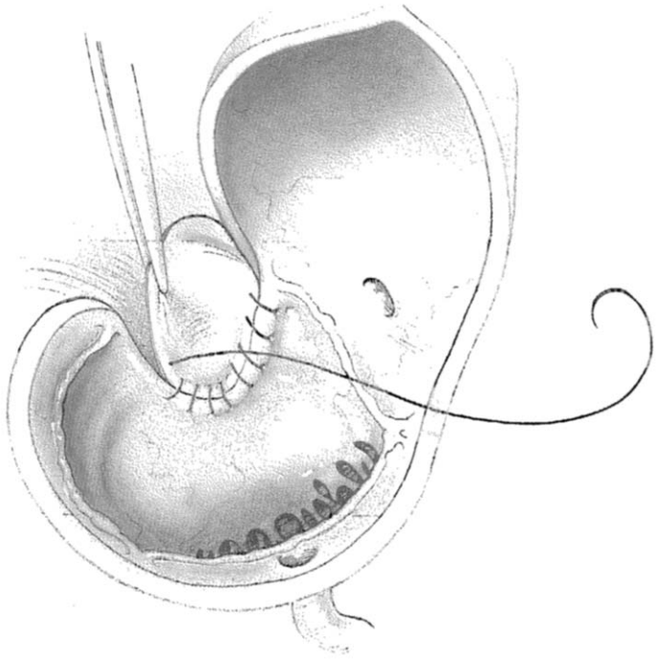


3 The heart is arrested after the application of the aortic cross clamp (Fig 3). Although, retrograde cardioplegia can be employed and might be preferred by some (especially with associated aortic insufficiency) we often employ an antegrade route of delivery for the cardioplegia. If necessary, further plegia can be administered directly into the coronary ostia after opening the ascending aorta. Initially, only a small transverse incision is made in the ascending aorta, through which the aortic valve complex is inspected. In the absence of change in plan of the operation (eg, change to Konno) the incision is extended in an oblique fashion toward the commissure between the LCC and the NCC. The aortic valve is inspected and the valve leaflets are excised. A prosthetic valve sizer is then employed to determine the size of the native annulus.

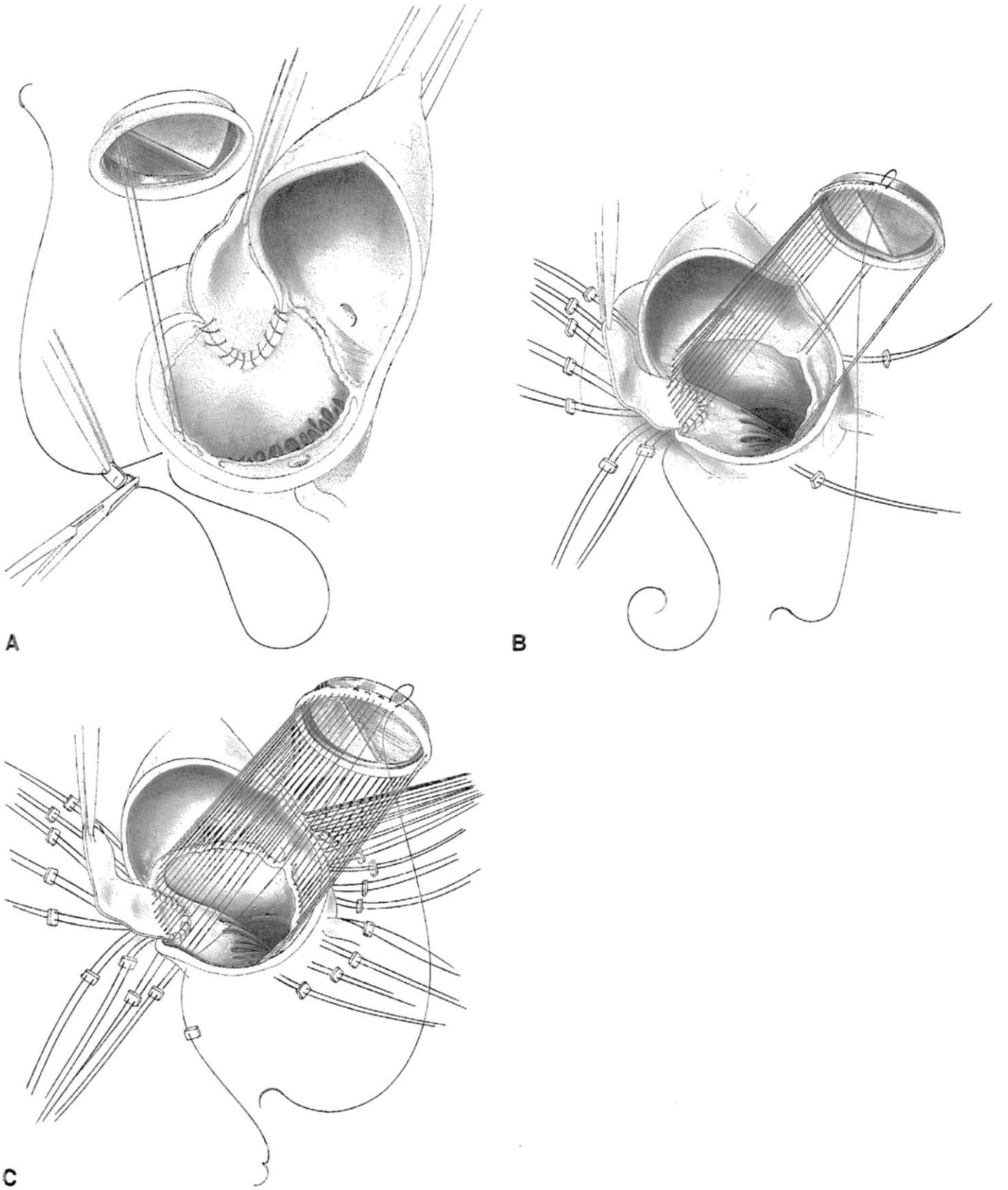


A B

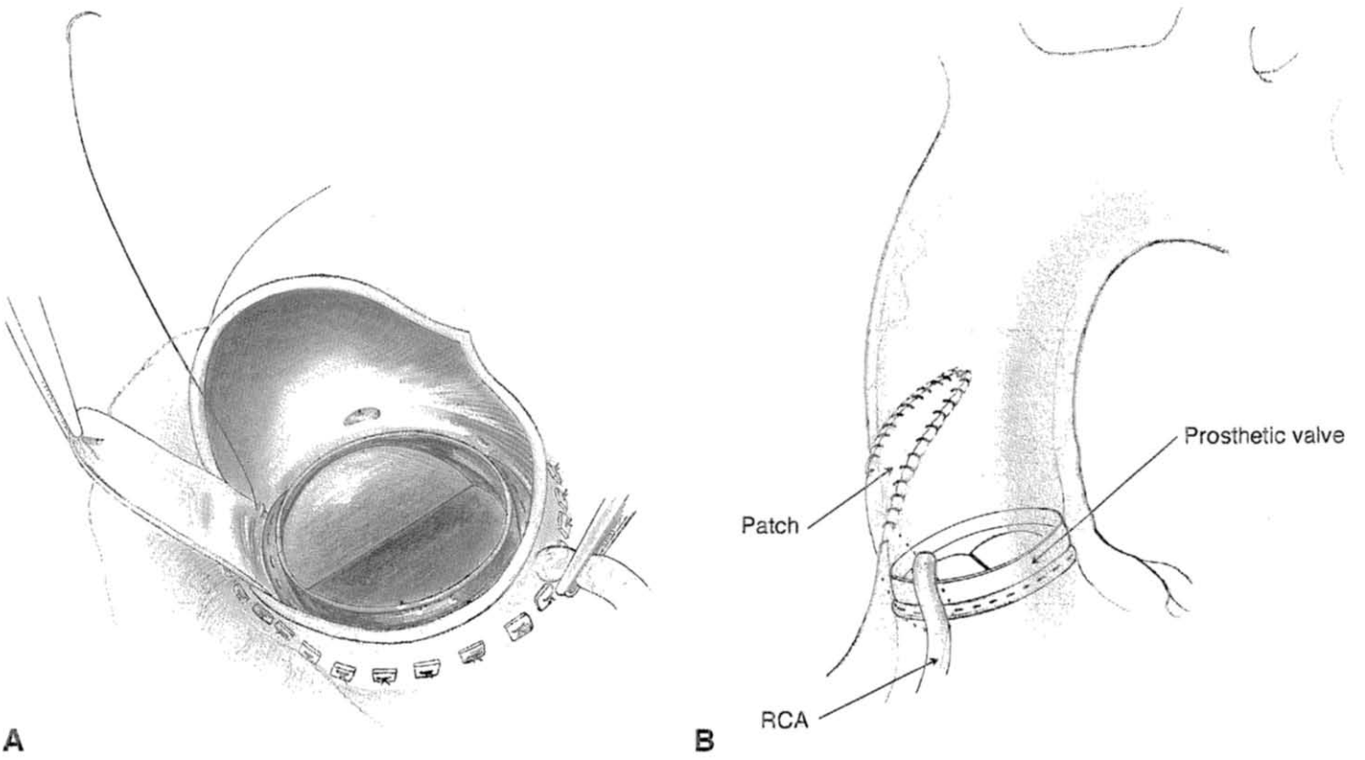
4 Once it has been established that the sizer does not comfortably pass through the aortic annulus, the aortic incision is further extended from the top of the NCC-LCC commissure to just above the confluence of the interventricular fibrous trigone (Fig 4). If need be, the incision can be taken down onto the mitral annulus and the left atrial wall. Typically, up to 10 mm of extension can be performed before encroachment on the mitral apparatus. This would correspond to about 15–18 mm enlargement along the arc of the aortic annulus. In the case of a borderline annulus, it is safer to still proceed with "controlled" enlarging cut since, the forcing in of a prosthetic valve may lead to an "uncontrolled" tear of the aortic root. Furthermore, a poorly seated aortic prosthetic valve is a substrate for paravalvular leak.



5 A teardrop shaped pericardial patch is then sutured with 4.0 polypropylene suture to the incised fibrous trigone and aortic wall (Fig 5). In rare instances, the incision is extended substantially down the AML, necessitating the use of a diamond shaped patch. Others have utilized a two patch technique with good results, placing two triangle-shaped patches joined at a hinge point that corresponds to the level of the annulus. Using this latter approach, Molina and coworkers have demonstrated continued pliability and mobility of the anterior leaflet of the mitral valve and the complete absence of any subsequent mitral regurgitation.[14]



6 Repeat sizing is performed to ensure the adequacy of the enlargement and to assess the size of the required prosthetic valve. Interrupted pledgeted sutures are placed through the sewing ring of the valve, passed through the aortic wall and then finally, through a small pledget. On completion, all pledgets rest outside the ascending aorta. In this fashion, no pledget material is encroaching into the space reserved for the inserted valve, maximizing the space available for the seating of the prosthesis. Furthermore, the knots can be tied easily outside of the aorta, without any damage or stress to the fragile reconstructed root. Special attention is required during the placement of the sutures under the coronary buttons.



7 After seating the valve and inspecting the suture line, the remainder of the patch and the aortic wall are closed in one layer. It is important that the previously prepared patch is appropriately sized, since a small patch can lead to supravalvar stenosis and a large patch can lead to distortion of the aortic root (and aortic insufficiency). After appropriate de-airing maneuvers, the aortic cross-clamp is removed and cardiac action resumed. The right coronary is gently occluded during the de-airing process as an added measure of safety. During these early moments, the aortic root is inspected closely for hemostasis and absence of any distortion to either of the coronary arteries. Once rewarming is completed, cardiopulmonary bypass is terminated. Intraoperative echocardiography is then employed to confirm the absence of any residual intracardiac air, the adequacy of ventricular function, absence of any mitral regurgitation, and absence of any perivalvular leak or prosthetic valve related problems.

COMPLICATIONS

Because of the proximity to the mitral valve apparatus, mitral regurgitation is a potential complication of this approach.[15] Interestingly, the mitral regurgitation typically does not present until late follow up, typically 5–10 years postoperatively.[12–14,16] Surprisingly, the mitral regurgitation is not simply associated with the extent of the incision, but rather with the use of synthetic patch material, since the pathology has not been reported in patients in whom autologous pericardium has been used. With this particular problem on echocardiography the basal portion of the AML appears highly echogenic and with poor mobility. Therefore, the marginal portion of the anterior leaflet appears to have relative prolapse compared with the basal portion, with a "hinge" joint in the midportion of the AML. The resultant regurgitant flow is directed toward the posterior wall of the left atrium.

Other reported complications include left atrial to aorta fistula,[17] hemolysis secondary to the use of Dacron patch material,[12] and prosthetic valve related complications such as perivalvular leakage and endocarditis. If the AML is incised to any degree more than just minimal, then it is prudent to re-enforce the attachment of the patch to the leaflet tissue and to ensure absence of any tension on those suture lines as demonstrated by the reported complication of acute mitral regurgitation postoperatively because of separation of the patch material from the AML.[10]

RESULTS

Many long-term retrospective studies published on the outcome of the Manouguian approach demonstrate the long-term efficacy of this procedure.[12,13,16] Nearly all reoperations are because of failure of the prosthetic valve. The most common reported complication relates to mitral regurgitation (0 to 14%).[12,13,16,18] Most studies have demonstrated the superiority of the annular enlarging procedures to placement of small valve prostheses. Unfortunately however, none of these studies have focused on the pediatric population solely and are rather a compilation of both adults and children. Nev-

rtheless, the posterior annular enlarging procedure emains a useful adjunct to the armamentarium of the ongenital heart surgeon.

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